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DURABILITY OF FLAME-RESISTANT COTTON FLANNELETTE TO LAUNDERING WITH SELECTED DETERGENTS

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ish and fabric of six 100% cotton flannelettes intended for children's sleepwear.

MATERIALS AND METHODS

Fabric I was treated with Pyrovatex flame-retardant finish. Fabrics II, III, and IV were treated with three unknown modifications of the Pyrovatex finish. Fabrics V and VI were finished with tetrakis-(hydroxymethyl)phosphonium hydroxide-ammonia (THPOH-NH_3) by two different applicators. Fabrics I and VI were representative of commercial fabrics available to the public, and the other fabrics were pilot-plant productions of advanced experimental finishes.

The detergents represented four builder types: A, a powdered detergent, contained a high-phosphate builder; B, also powdered, contained a carbonate builder; C, a heavy-duty liquid detergent, contained a low-phosphate builder; and D, another heavy-duty liquid detergent, contained a citrate builder. All detergents are available at retail stores under brand names.

Each fabric was laundered up to 50 times with the detergents by the AATCC method. After a preestablished number of launderings, the durability of the flame-resistant finish and of the fabric was tested.

Fabric flammability was tested as specified in DOC FF 3-71. Nitrogen loss and calcium buildup in the laundered fabrics, also measures of finish durability, were determined respectively by the micro-Kjeldahl method and atomic adsorption spectrometry. Three physical properties, indicators of fabric durability, were measured by ASTM meth-

ods:⁴ the raveled-strip method for breaking strength, the falling-pendulum (Elmendorf) method for tearing strength, and the flexing and abrasion method for abrasion resistance.

RESULTS AND DISCUSSION

The effect of detergent type on fabric flame resistance varied (table 1). Detergent A, containing the high-phosphate builder, caused little or no reduction in the flame resistance of fabrics I and VI after 50 laundry cycles, but fabric III failed after 40 cycles, and fabric V, after 20 cycles. (Fabrics II and IV were not laundered with detergent A.)

With the carbonate-built detergent (B), only fabric VI passed after 50 laundry cycles. Fabric V failed after 10 cycles; fabrics I, II, and IV failed after 15 cycles; and fabric III, after only 5 cycles.

With the low-phosphate liquid detergent (C), fabrics II, IV, and VI passed the flame test after the required 50 laundry cycles. After 40 laundry cycles, one specimen of fabric I and one of fabric V burned the entire length (BEL). Fabric III failed after 20 cycles because its average char length exceeded the maximum allowable 7 inches.

Results for the citrate-built detergent (D) were similar to those for detergent C: the same fabrics (II, IV, and VI) passed the flame test after 50 laundry cycles. A single specimen of fabric V burned its entire length after 50 cycles, pro-

⁴ American Society for Testing and Materials. ASTM Designations D 1424-63, D 1682-64, and D 1175-64.

TABLE 1.—Results of flammability tests on laundered fabrics¹

Number of laundering	Average char length (inches)							
	1	5	10	15	20	25	40	50
Fabric I:								
Detergent A	2.9	2.9	3.3	3.1	2.9	3.4	2.7	2.9
B	3.6	...	...	BEL	...	...	...	...
C	3.7	...	3.9	...	...	4.6	5.8*	BEL
D	3.2	...	4.3*	3.0	...	3.9*	6.4*	4.6*
Fabric II:								
Detergent B	2.4	...	...	BEL	...	...	...	...
C	2.8	...	3.2	2.3	...	2.3	3.5	2.6
D	2.2	...	2.8	2.6	...	2.8	2.8	3.5
Fabric III:								
Detergent A	...	4.9	5.6	...	6.2	...	7.6*	...
B	...	9.3*	BEL	...	...	...	...	...
C	...	3.9	4.9	...	7.1	...	5.9	6.2
D	...	6.0	7.8	...	7.3	...	...	...
Fabric IV:								
Detergent B	2.2	...	...	BEL	...	...	...	...
C	2.7	...	2.5	3.4	...	2.8	1.8	3.8
D	2.4	...	2.6	2.6	...	2.2	2.9	3.0
Fabric V:								
Detergent A	...	2.1	3.7	...	5.1*	...	2.1	...
B	...	1.7	5.7*	...	BEL	...	...	...
C	...	2.3	2.4	...	2.6	...	5.8*	BEL
D	...	2.0	2.0	...	3.4	...	3.7	7.3*
Fabric VI:								
Detergent A	...	1.1	1.3	...	.8	...	.9	1.1
B	1.6	...	...	1.6	...	1.4	2.6	2.0
C	1.4	1.5	1.6	.8	1.6	1.4	1.5	1.5
D	1.4	1.5	1.4	2.0	1.2	2.8	1.3	1.3

¹ BEL indicates that all specimens burned entire length. * indicates that 1 or more specimens burned entire length. A fabric fails DOC FF 3-71 standards when 1 or more specimens burn their entire length or when the average char length of specimens in a test lot exceeds 7.0 inches.

ducing an average char length of over 7 inches. A single specimen of fabric III burned its entire length after 20 cycles, and a single specimen of fabric I failed after 10 cycles.

The organophosphorus flame-retardant finishes used in this study contain a coreactant nitrogen compound that acts as a fixative. To impart good flame resistance, these compounds must provide the finished fabric with a particular amount of nitrogen. For example, a fabric should contain at least 1.8%

nitrogen after treatment with a certain Pyrovatex finish⁵ and 2% to 2½% after the usual THPOH-NH₃ treatment.⁶ Thus, the nitrogen content of finished fabrics is a measure of finish durability.

Figure 1 presents nitrogen content as a function of the number of laundry cycles. (In this and subse-

⁵ Ciba-Geigy Rev. 1968/1: 43-48.

⁶ Personal communication, G. L. Drake, Jr., Southern Regional Research Center, Agricultural Research Service, New Orleans, La.

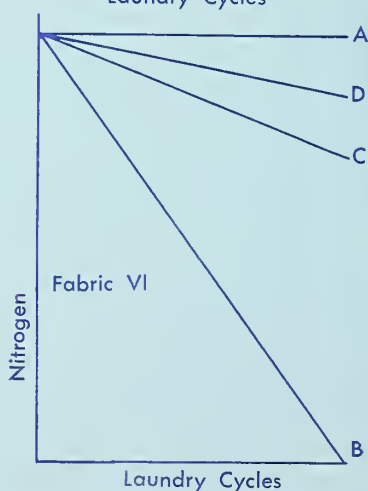
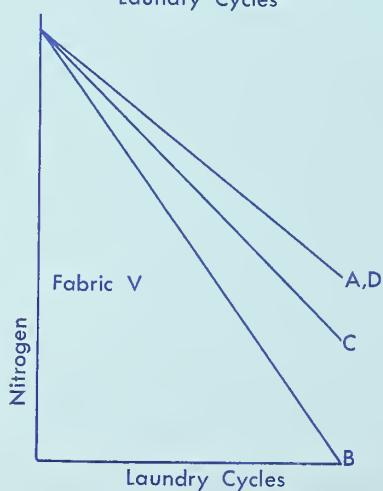
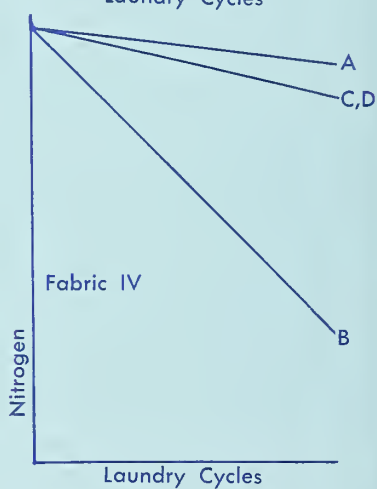
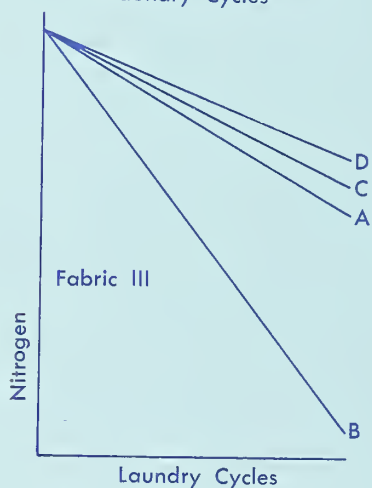
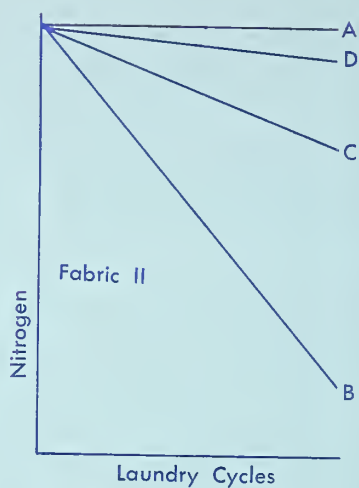
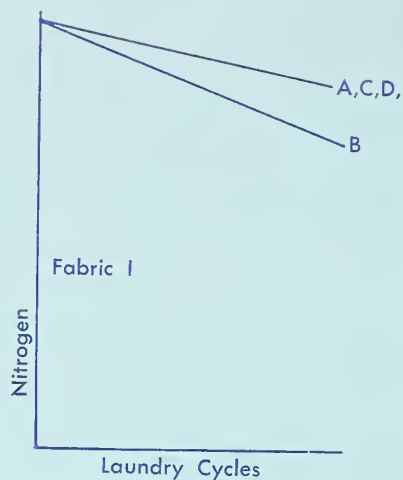


FIGURE 1.—Laundering effect on nitrogen content of finished fabrics.

quent figures, regression lines were calculated and normalized to facilitate comparisons.) Nitrogen loss varied from 0% to 5% with detergent A, from 19% to 36% with B, from 10% to 15% with C, and from 4% to 12% with D. Not only was the greatest percentage loss with detergent B, but rate of loss also was greatest. Overall resistance to loss of nitrogen was best in fabrics I and VI. For the high-phosphate detergent (A), loss of nitrogen was negligible from fabrics II and VI, slight from I and IV, and somewhat greater from III and V. Nitrogen loss from all fabrics was greatest for the carbonate-built detergent (B). The citrate-built detergent (D) caused as little or less loss of nitrogen as the low-phosphate detergent (C).

Early failure of an otherwise durable flame-resistant finish is often attributed to a buildup of calcium from hard water used in laundering. Figure 2 shows calcium buildup in each fabric. Buildup was especially great when detergent B was used. In order of increasing effect on calcium buildup, detergents ranked A, D, C, and B. The order is similar to that for the detergent effect on decreasing nitrogen content: A had least effect; B, most. Calcium content was determined on specimens after 50 laundry cycles with a detergent and the values averaged for the four detergents. The fabrics were then ranked in order of increasing calcium content, as follows: VI, V, I, II, IV, III. The lowest calcium content of fabric VI must have contributed to its better performance in the flame test after repeated laundering.

The effects of the detergents on breaking strength, tearing strength, and flexural abrasion resistance of four fabrics are shown in figures 3-5.

The effect of a given detergent on breaking strength was not consistent (fig. 3). Differences among detergents were less in fabrics I and VI than in fabrics II and IV. The carbonate detergent (B) reduced breaking strength less in fabric I than in any other fabric. The high-phosphate detergent (A) was not as effective in preventing breaking strength loss as it was in preventing early failure in the DOC FF 3-71 flammability test.

After repeated laundering, loss of tearing strength was greatest in fabric I (fig. 4). Detergent A caused less loss than the other detergents in three of the fabrics, but differences among detergents generally were small. Retention of tearing strength was best in fabric VI with all detergents used.

The effect of repeated laundering with detergent A on abrasion resistance was surprising (fig. 5). Detergent A not only was least harmful but even improved abrasion resistance. This effect was not explained. The other three detergents caused the expected reduction in abrasion resistance; reduction was somewhat less in fabric VI than in the other fabrics.

CONCLUSIONS

Fabric VI, having a THPOH-NH_3 finish, retained its flame resistance and tearing strength slightly better than the other fabrics tested

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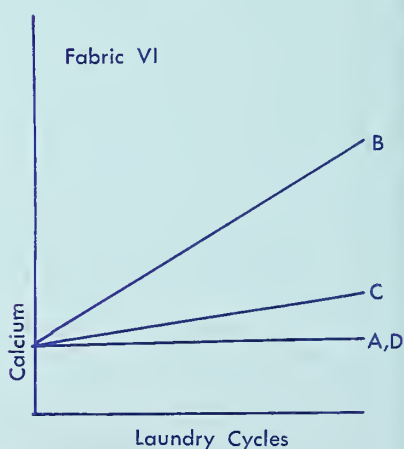
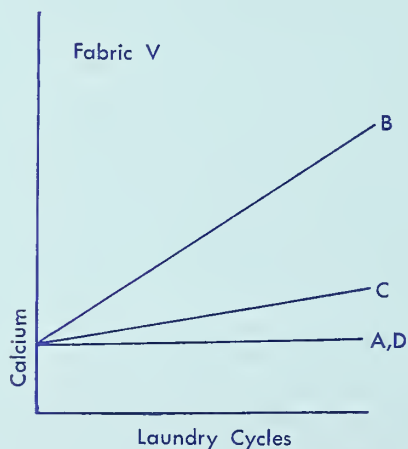
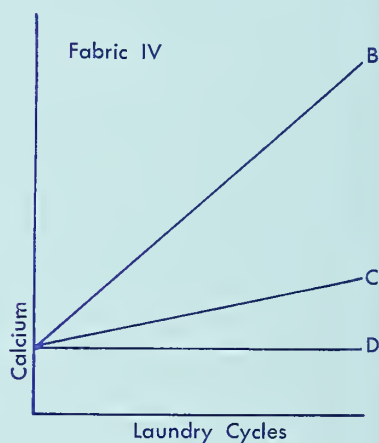
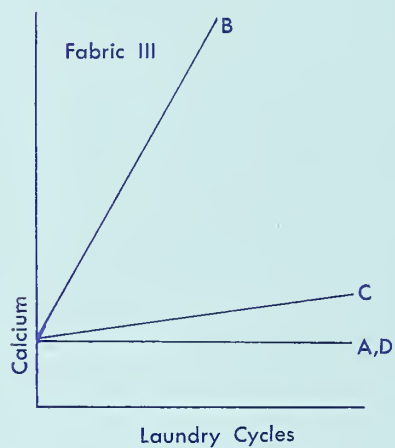
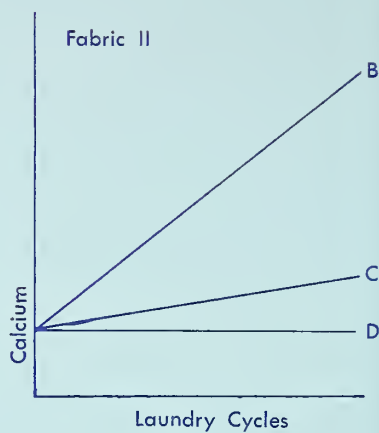
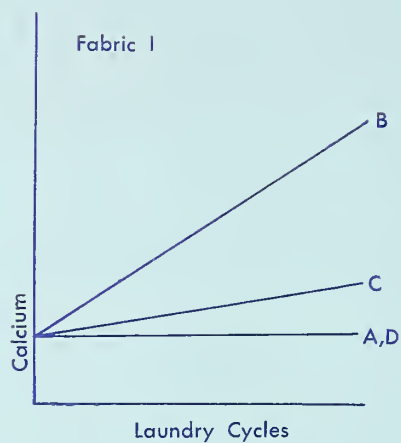


FIGURE 2.—Laundering effect on calcium buildup in fabrics.

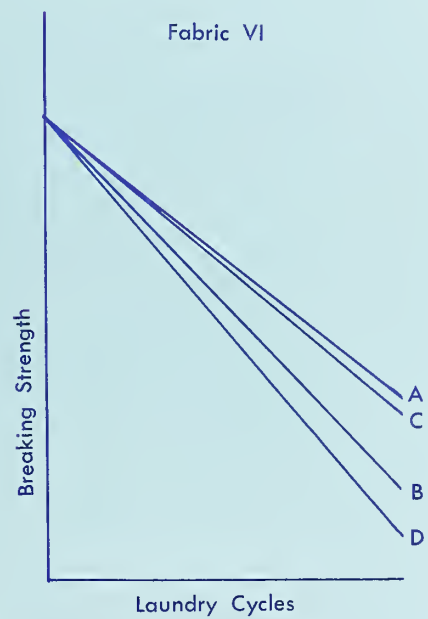
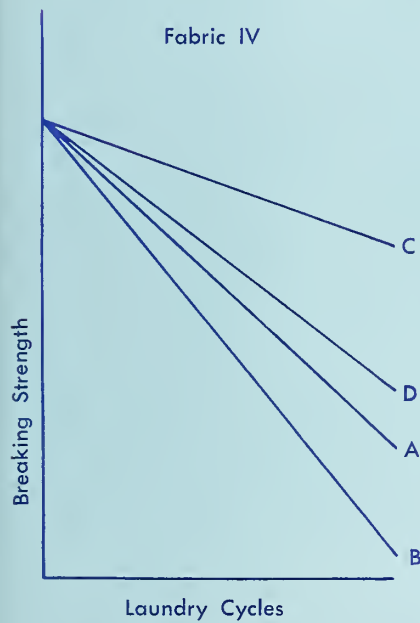
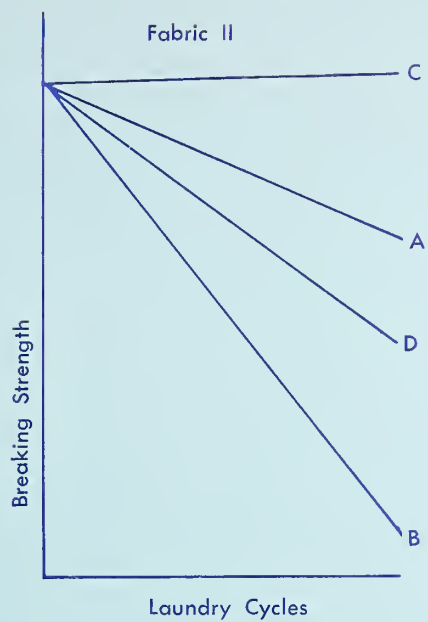
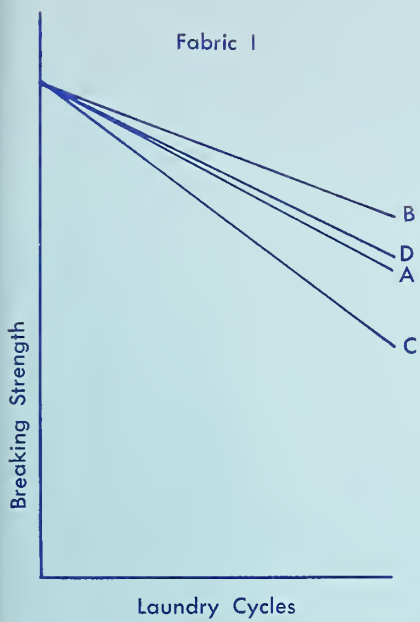


FIGURE 3.—Laundering effect on fabric breaking strength.

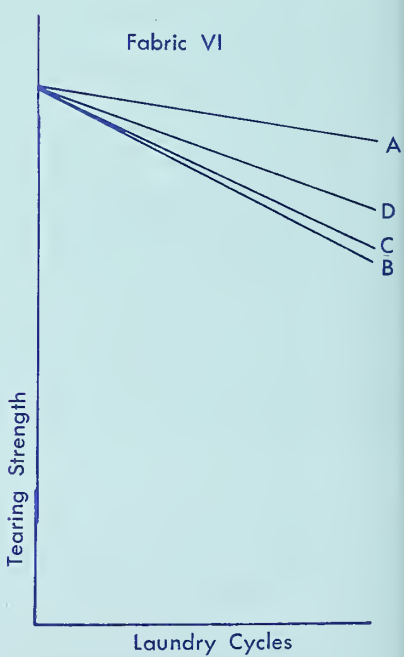
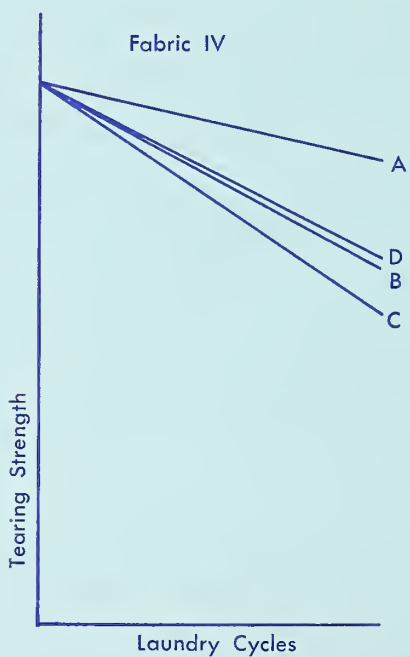
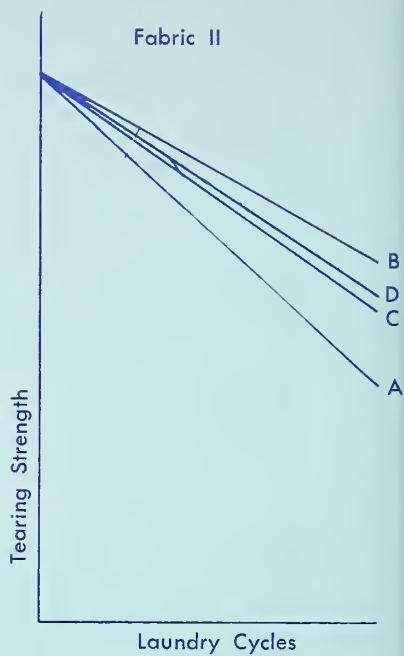
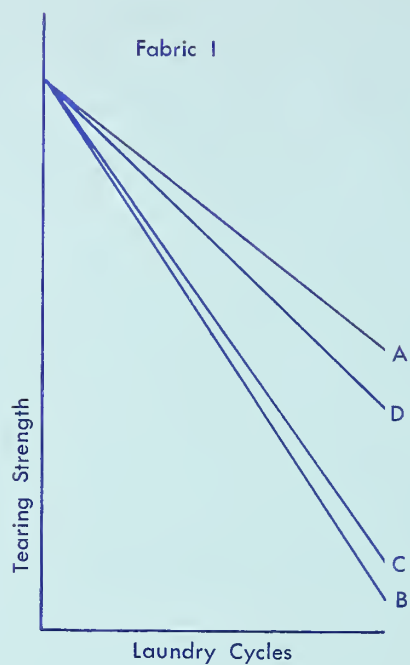


FIGURE 4.—Laundering effect on fabric tearing strength.

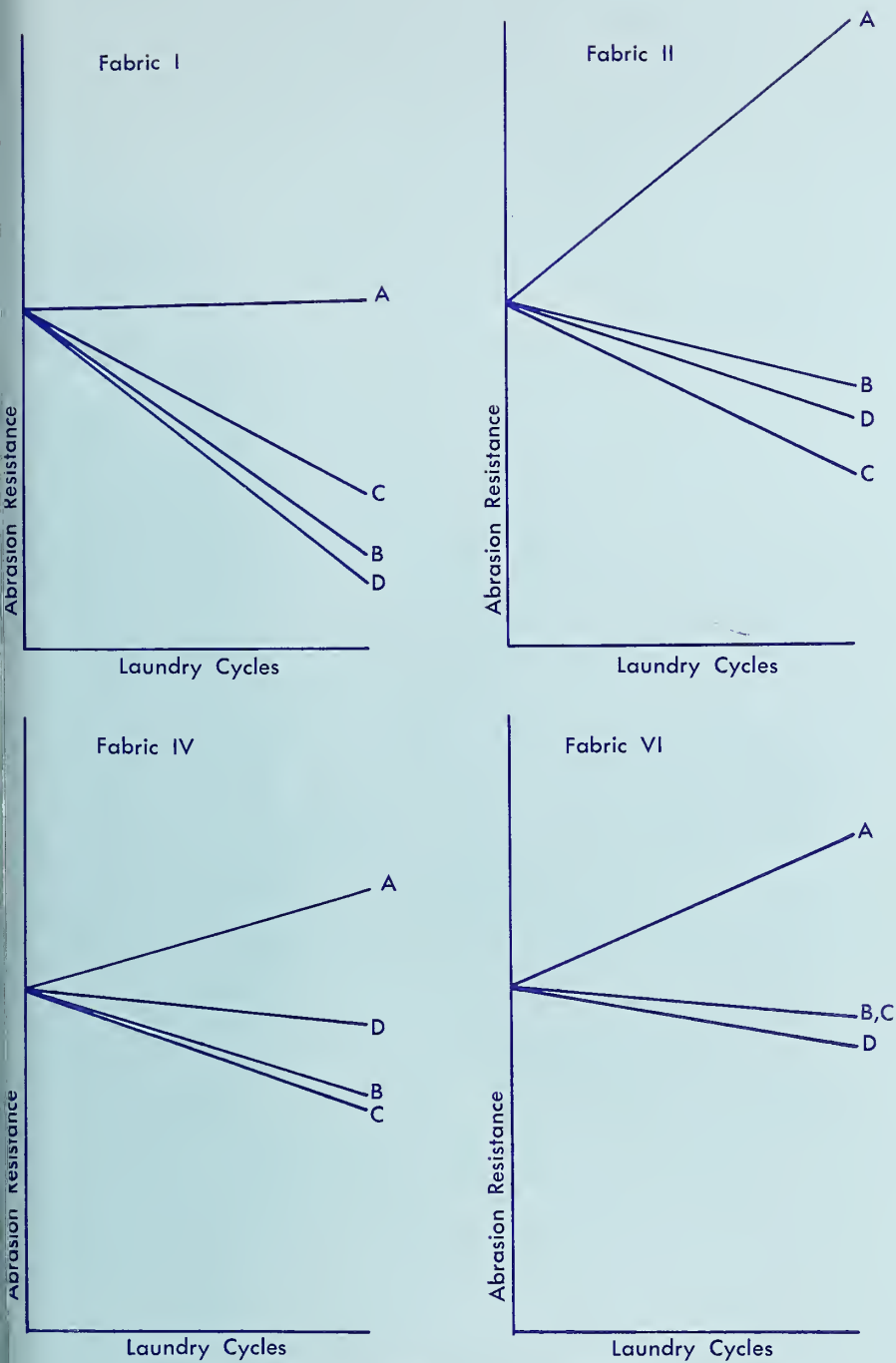


FIGURE 5.—Laundering effect on fabric abrasion resistance.

in all detergent systems. It also exhibited good resistance to loss of nitrogen and had greater resistance to calcium buildup than the other fabrics. The carbonate-built detergent (B) was more damaging to flame resistance, nitrogen content, and calcium content than the other detergent systems on all fabrics. In general, the effects of all detergent systems on breaking strength and tearing strength were similar for all

fabrics. The effects of all detergents except detergent A on abrasion resistance were similar. Detergent A produced unexpected and unexplained improvement in abrasion resistance of three of the fabrics tested.

ACKNOWLEDGMENT

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ABOUT THE TEXTILES AND CLOTHING LABORATORY

Research interest in textiles and clothing by the U.S. Department of Agriculture became a reality in 1915 with the establishment of the Cooperative Extension Service. This was continued in the Bureau of Home Economics formed in 1923. The Agricultural Research Service, established in 1953, continued textile and clothing research in its laboratories at Beltsville, Md., until relocation of the Textiles and Clothing Laboratory at Knoxville, Tenn., in 1966. Present research studies include—

- identification, description, and establishment of levels for the properties required in textile products to meet the needs and wants of consumers;
- development of principles and information basic to the improvement of the design and construction of household textiles and apparel, as related to properties such as comfort and durability;
- development of improved techniques for laundering, disinfecting, and otherwise caring for clothing and household textiles to improve service life and to insure safety to health;
- establishment of the nature and degree of deterioration of textile products occurring during wear, home storage, and reconditioning;
- development of information basic to improvement in the sizing of clothing; and
- development of objective methods for evaluation of textile product properties which will predict service life.